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The effects of caffeine on video head impulse test results

Elizabeth Zakrzewski
zakr4034@bears.unco.edu

UNIVERSITY OF NORTHERN COLORADO

Greeley, Colorado

The Graduate School

THE EFFECTS OF CAFFEINE ON VIDEO HEAD IMPULSE TEST RESULTS

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Elizabeth Anne Zakrzewski

College of Natural and Health Sciences
School of Human Sciences
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has been approved as meeting the requirement for the Degree of Doctor of Audiology in the College of Natural and Health Sciences, School of Human Sciences, Audiology and Speech-Language Sciences Program

Accepted by the Capstone Research Project Committee

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Tina M. Stoody, Ph.D., Co-Research Advisor

_____

Kathryn Bright, Ph.D., Co-Research Advisor

_____

Gary Heise, Ph.D., Faculty Representative

Accepted by the Graduate School

_____

Cindy Wesley, Ph.D.
Interim Associate Provost and Dean
Graduate School and International Admissions

ABSTRACT

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Prior to administering vestibular evaluations, clinicians often instruct their patients to abstain from several different substances including caffeine. Regarding the video head impulse test (vHIT), research addressing the effect of caffeine is lacking. The purpose of this research was to determine what, if any, effect caffeine had on the results of the vHIT. Participants included 19 healthy adults who were divided into two groups. Group 1 was given caffeinated coffee and group 2 was given decaffeinated coffee. The vHIT was performed on each participant at two points in time—after abstaining from caffeine for 24 hours and then again after consuming a 12-ounce cup of coffee. Vestibulo-ocular reflex (VOR) gain values were measured for both groups before and after coffee consumption. Two independent samples *t*-tests were performed using the difference values from pre- and post-coffee consumption tests to compare the two groups—one test using the absolute values and one not. While the *t*-test performed using the absolute values showed a significant difference between groups ($t(27.435) = 2.751$, $p = .01$), suggesting a greater amount of variability in VOR gain changes in group 1, the results of the *t*-test performed without absolute values was not significant ($t(25.698) = .028$, $p = 0.978$), indicating these changes in VOR gain values were not consistently either increases or decreases in gain. Despite obtaining significant results in the *t*-test using absolute values, the differences in VOR gain as well as number of saccades

observed in each group were not clinically significant, i.e., all participants in both groups would have been classified as having normal test results in a clinical setting regardless of coffee consumption. The results of this study suggested abstaining from caffeine might not be necessary when performing the vHIT clinically. The results of this study might be useful in helping those who perform vHIT clinically to know how to best prepare their patients for this vestibular evaluation.

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CHAPTER I

STATEMENT OF THE PROBLEM

Vestibular disorders, disorders affecting the control of balance, can affect all age groups. These disorders tend to affect women more than men with a general trend toward an increase in prevalence with age (Hülse et al., 2019). When considering unspecified symptoms of vertigo or dizziness, Hülse et al. (2019) found 4.8% of the population to be affected. The sensation of dizziness can greatly impact a person's quality of life with those who are affected scoring significantly lower on both mental and physical quality of life measures (Weidt et al., 2014). These reduced scores could be related to both the effect of the dizziness itself as well as psychosocial factors such as emotional distress and education (Weidt et al., 2014).

The ability for a person to maintain balance comes from the combination of three systems: vestibular, visual, and proprioceptive. Because balance involves the cooperation of these systems, many causes of dizziness need to be tested for and ruled out to best address a patient's complaints. In diagnosing and treating vestibular pathology, often a team-based approach is used: an audiologist can perform balance testing, an otolaryngologist or neurologist can assist in further examination and a formal diagnosis, a physical therapist can perform gait and balance testing, and a radiologist can perform imaging (Hatton, 2019). When examining and diagnosing the cause of a patient's dizziness, a variety of tests are available for differential diagnosis.

Audiologists need to be able to determine if symptoms are results of a peripheral pathology or central pathology. A peripheral pathology is one that originates from dysfunction of cranial nerve VIII and the distal vestibular organs (Thompson & Amedee, 2009). Symptoms of a peripheral vestibular pathology involve vertigo and possible related nausea, horizontal nystagmus, or eye movements that beat away from the "impaired" side, and postural impairments that could include falling toward one side, difficulty walking straight, and instability in dim or dark rooms (McCaslin, 2013). A central pathology or central findings in a vestibular test battery involve structures other than the vestibular organs and cranial nerve VIII and could result in vestibular symptoms. These structures could involve the oculomotor system, vestibular nuclei, cerebellum, extraocular nuclei, and spinal cord with pathways including the vestibulocerebellar tract, vestibulospinal tract, and vestibulocortical tract (Lui, Foris, Willner, & Tadi, 2019). Symptoms involved in a central pathology include dizziness that is described as more of a disequilibrium, nystagmus that is vertical or torsional and could change direction with gaze, and dizziness that might be accompanied by other neurological symptoms (Thompson & Amedee, 2009).

When testing for pathologies related to or causing dizziness, audiologists often give their patients a set of instructions before testing in order to yield the most accurate results. Many medications or substances could affect test results such as central nervous system (CNS) stimulants and depressants (Judson & Galatioto, 2017). Central nervous system depressants could cause abnormal eye movements, a decrease in alertness, and a false vestibular hypofunction finding, while CNS stimulants could increase vestibular responses (Judson & Galatioto, 2017). Therefore, pre-test instructions typically include a

list of things to abstain from for a period of time before the test such as alcohol, non-essential medications, and nicotine, which might impact the test results.

One substance a patient is often told to forgo prior to vestibular testing is caffeine as it is thought to affect the results of testing. Caffeine ("Caffeine," 2019) is most often used as a central nervous system stimulant, helping those who use it feel more awake and alert as well as increasing muscle twitches. Caffeine might also affect cognitive processes involved with visual attention (Connell, Thompson, Turuwhenua, Hess, & Gant, 2017). Additionally, caffeine's stimulant properties have been labeled as a trigger for symptoms in vestibular disorders such as Meniere's disease (Sánchez-Sellero, San-Román-Rodríguez, Santos-Pérez, Rossi-Izquierdo, & Soto-Varela, 2017). However, researchers have found that caffeine might not have as large of an effect on results of vestibular testing as was previously thought (Felipe, Simões, Gonçalves, & Mancini, 2005; McNerney, Coad, & Burkard, 2014b).

A relatively new test in the vestibular evaluation battery is the video head impulse test (vHIT). The vHIT evaluates the functionality of the semicircular canals, one of the vestibular structures within the inner ear (Judson & Galatioto, 2017). This evaluation is performed by the clinician through the use of video goggles that track a patient's eye movements in relation to head movements.

Because the video head impulse test (vHIT) is a relatively new vestibular evaluation, there is limited research regarding the effect of substances such as caffeine on the test results. Knowing the effects of caffeine intake, or lack thereof, is an important piece of performing the vHIT so providers can know how to have their patients prepare

for testing to ensure the most accurate results are obtained. Therefore, the following research question and hypothesis were addressed with the current research study:

Q1 After a baseline test in a caffeine-abstained condition, is there a significant difference in the change in vestibulo-ocular reflex (VOR) gain values recorded by the video head impulse test (vHIT) when comparing a group of adults who ingested caffeine to another group of adults who ingested a decaffeinated beverage?

H01 There will be no significant change in VOR gain between a caffeine abstained baseline vHIT test and a post coffee consumption vHIT test, regardless of caffeine content within the coffee beverage.

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

The vestibular system is just one of three physiological systems that allows us to maintain our balance. Also connected to the maintenance of balance are vision and proprioception. A disruption of the intricate collaboration of these three systems could cause a variety of symptoms ranging from mild to debilitating. With the complexity of balance, different tests are needed to evaluate various portions of the vestibular system and other systems involved. However, these tests can sometimes only give a general sense of a diagnosis or even just a possible location of the issue. Using the video head impulse test (vHIT), a portion of the vestibular system (the semicircular canals) can be evaluated with a much higher degree of detail and specificity than previously available. Rather than generalizing the problem to a "peripheral" location when there is an issue in the semicircular canals, each of the six canals can be considered individually. In addition, the head impulse test is quicker and more efficient than videonystagmography for identifying abnormalities associated with the semicircular canals.

The Vestibular System

While it is commonly understood that the ears contribute to hearing via the auditory system, the other contribution they make involves a person's sense of balance through the vestibular system in the inner ear. By working together with the vision and proprioceptive systems, the vestibular system accomplishes three tasks: (a) provides

information to the CNS to control skeletal muscle tone and posture, (b) stabilizes vision when either a person or the surroundings are in motion, and (c) sends information about linear and angular spatial movements to the CNS (McCaslin, 2013).

The vestibular system is made up of five organs in each inner ear: the utricle, saccule, and three semicircular canals. These structures are part of a membranous labyrinth located within a bony labyrinth in the temporal bone. This labyrinthine structure also makes up the cochlea—the portion of the inner ear responsible for hearing. This labyrinth and each of the structures it houses are filled with fluid called endolymph.

Semicircular Canals

The balance organs within each inner ear include a trio of semicircular canals (SCC): lateral (horizontal), posterior (superior), and anterior. These canals are orthogonal, meaning they are positioned at right angles to each other, and allow for head movement in any direction to be detected. Each semicircular canal functions as a pair with another canal on the contralateral side (Brandt & Strupp, 2005). The two lateral canals are paired as well—the right anterior canal with the left posterior canal (RALP) and the left anterior with the right posterior (LARP). By working in pairs, when one semicircular canal is activated, its counterpart on the opposite side is inhibited to help enhance a response. Certain terminology is used to describe the planes of excitation: pitch describes rotation around the y-axis, yaw around the z-axis, and roll around the x-axis. Figure 1 shows a diagram of these planes.

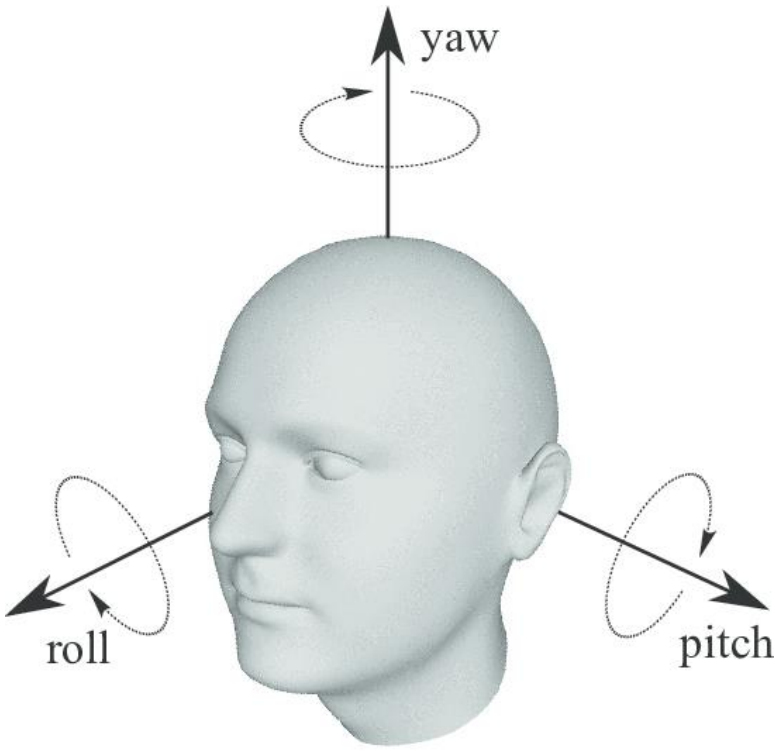

Figure 1. Pitch, yaw, and roll in relation to head movements along each axis (Fernández Villán, Usamentiaga, Carús, & Casado, 2016).

At one end of each canal, there is an enlarged structure called the ampulla (McCaslin, 2013). Inside the ampullae are the cristae ampullaris, which are the sensory epithelium of the canals. The crista ampullaris has several components including the cupula, which is a gelatinous structure that divides the ampulla into two sections. The stereocilia of the sensory hair cells are embedded in the base of the cupula.

The two types of sensory hair cells within the vestibular organs perform slightly different functions. In the semicircular canals, the type I hair cells are located at the center of the crista ampullaris and are thought to provide quick bursts of neural information that allow head adjustments when the canals are activated (McCaslin, 2013).

Meanwhile, type II hair cells are located more at the edges of the crista ampullaris, contributing to the neural control of the eye movements of the VOR. The hair cells have stereocilia that increase in height with a longer structure called a kinocilium at the end of the bunch. The hair cells are positioned so deflection of the hair cells in one direction, toward the kinocilium, causes depolarization or an increase in the firing of the neurons, and deflection away from the kinocilium causes inhibition of the neuron (McCaslin, 2013).

Otolith Organs

While the semicircular canals are responsible for tracking rotational movements, the utricle and saccule, the two otolith organs of the vestibular system, detect and code for linear movement and acceleration (McCaslin, 2013). The utricle senses head movements in the horizontal plane (left and right, forward and backward), while the saccule detects movement in the vertical plane (up and down). In each of these organs is a sensory structure called the macula. The maculae have a gelatinous portion called the otolithic membrane in which otoconia, or calcium carbonate crystals, are embedded (McCaslin, 2013). As the head moves, the otolithic membranes shift due to gravity. Sensory hair cells in the saccule and utricle have cilia projected into the otolithic membranes. These hair cells are activated by the shifts of the otoconia along with the movement of the otolithic membrane. The orientation of the hair cells is complex, allowing for planar motion in nearly any direction to be detected. A line of small otoconia, called a striola, divides each macula into two parts with the hair cells in the saccule oriented away from this line and the hair cells in the utricle oriented toward this line (McCaslin, 2013).

Reflexes and Neural Pathways

The axons projecting from the vestibular organs collect to form the superior and inferior vestibular portions of cranial nerve VIII, the vestibulocochlear nerve. These axons project to the vestibular nuclei (VN) in the brainstem that include the superior, lateral, inferior, and medial nuclei. While all fibers from the saccule and utricle and most fibers from the SCCs go to these nuclei, some fibers from the SCCs bypass the VN and go directly to the cerebellum through the vestibulocerebellar tract (Netter, 1983).

In addition to the input from the vestibular structures, the VN also receives input from the spinal cord and reticular formation as well as the contralateral VN. From the VN, axon projections go in many directions. The vestibulospinal tract aids in motor control for the neck and limbs as well as postural regulation. The vestibulocortical tract delivers information to the thalamus and parietal lobe of the cortex (Netter, 1983). Lastly, the VOR is a reflex pathway that allows interactions between the VN and the cranial nerves involving eye movement including cranial nerves III (oculomotor), IV (trochlear), and VI (abducens).

Vestibulo-ocular Reflex

The VOR is an important aspect of the vestibular system. This reflex pathway causes eye movements in response to head movement and related vestibular system activation. Neural pathways for eye movements receive information from the VN, which, as stated above, is a group of neurons that receives input from the primary neurons of the vestibular system (McCaslin, 2013). This additional information to the visual pathways allows a person to adjust vision and focus on objects while moving. The

VOR has a latency of less than 10 msec, which is fast enough for a person to make quick visual adjustments during normal activity (Backous & Cloutier, 2017).

Various types of VOR responses occur based on the movement and resulting sensory input. The angular VOR responds to angular movement and acceleration and the activation of the SCCs (Backous & Cloutier, 2017). The associated eye movements for the angular VOR are equal and opposite to the head movements. The linear VOR is based on otolithic organ responses to linear acceleration. These eye movements are compensatory to translational movement, or movements from one point to another, and are affected also by the distance from the focus point (Backous & Cloutier, 2017).

The horizontal VOR is controlled by the lateral SCCs. A crossed neural response organizes the eye movements. Secondary neurons from the medial vestibular nucleus excite the contralateral CN VI, leading to rotation of the contralateral eye due to contraction of the lateral rectus muscle, a muscle that contributes to eye movement (Backous & Cloutier, 2017). Accompanying this activity, the contralateral CN VI has interneurons that excite the ipsilateral CN III, thus activating the ipsilateral medial rectus muscle. There are also inhibitory pathways that prevent activation of the ipsilateral lateral rectus and contralateral medial rectus muscles. This pattern of neural activation leads to a horizontal eye movement away from the activated lateral SCC (Backous & Cloutier, 2017). An additional neural pathway from the medial vestibular nucleus to the abducens nucleus, which controls CN VI, helps to control these eye movements by coding for eye position and velocity.

Vertical VOR responses are controlled by the anterior and posterior SCCs. Eye movements produced from activation of these canals are vertical and torsional (Backous

& Cloutier, 2017). This pattern of movement is due to the vertical and oblique orientation of the canals. Activation from the anterior canals goes from secondary neurons from the superior and ventrolateral medial vestibular nuclei, which then activate divisions of CN III and thus the ipsilateral superior rectus and superior oblique muscles (muscles of eye movement). There are also inhibitory pathways to the various muscles, all of which lead to elevation of the eyes as well as intorsion of the ipsilateral eye and extorsion of the contralateral eye (Backous & Cloutier, 2017). The activation pathway of the posterior canals produces the opposite effect with extorsion of the ipsilateral eye and intorsion of the contralateral eye in addition to depression of both eyes.

Vestibular Pathology Diagnosis

Because different systems work together to contribute to balance, a variety of tests are required to evaluate and differentially diagnose vestibular pathologies. The evaluations in a comprehensive vestibular test battery consider all three contributors to balance—the vestibular system, visual system, and somatosensory system (e.g., proprioception).

When evaluating vestibular disorders, several aspects contribute to a diagnosis: the type of vertigo (rotary vs. an imbalance), duration of vertigo, triggers or movements that exacerbate vertigo, and whether or not there are other concurrent issues such as auditory problems, neurological symptoms, or headaches (Brandt & Strupp, 2005). Vestibular pathologies are typically classified as either peripheral or central. A peripheral vestibular pathology refers to dysfunction in the vestibular organs and structures, e.g., the semicircular canals, otolithic organs, and vestibular nerve. A central vestibular pathology involves dysfunction within the portions of the CNS that contribute

to balance such as structures related to vision or proprioception including the brainstem, cerebellum, and cortex (Brandt & Strupp, 2005). With a comprehensive test battery, information can be gathered about the type and cause of the pathology.

Electronystagmography/ Videonystagmography

One type of vestibular diagnostic test is the electronystagmography (ENG) or videonystagmography (VNG). Both tests involve the same procedures but record the results in different ways. An ENG tracks eye movements with the use of electrodes placed near the outer edges of each eye. Each eye has an electrical charge called the corneoretinal potential with the front of the eye, or cornea, being positively charged and the back of the eye, or retina, being negatively charged (McCaslin, 2013). The electrodes placed on either side of the eyes detect the electrical changes as the corneas move closer or further away from each electrode and thus track the eyes in the horizontal plane. Electrodes placed above and below one of the eyes allow tracking in the vertical plane. The VNG tracks eye movements using goggles with a special camera that follows the movement of the pupils. This camera uses infrared technology to follow the reflective cornea to determine the location of the pupil. Mirrors placed at specific angles allow the cameras to analyze an image of the eye in which there is contrast between the pupil and iris, thus making the pupil easy to track (McCaslin, 2013).

The ENG/VNG test battery is composed of several components that can give insight regarding the origin of the pathology or dysfunction. Gaze, saccades, sinusoidal tracking, and optokinetics are all portions of the ENG/VNG that involve the patient following a dot (or dots) on a light-bar in front of them. Abnormal findings in these

portions of the test battery typically indicate the cause of the dysfunction lies somewhere in the central vestibular system or vision system (McCaslin, 2013).

Also included in the ENG/VNG test battery is positional and positioning testing. Positional testing involves changes in head and body position such as head turned to the right or left, sitting up or lying down, or lying on one side or the other to determine if head position triggers dizziness and nystagmus. With positioning testing, a common test is the Dix-Hallpike maneuver that involves rapid movement of the head and body to determine if the movement elicits dizziness and nystagmus. The Dix-Hallpike can help diagnose benign paroxysmal positional vertigo (BPPV), a peripheral vestibular pathology involving the displacement of the otoconia, causing bouts of strong vertigo. This maneuver involves turning a patient's head at a 45-degree angle as they are lowered from sitting to a supine position with their head hanging slightly off the test table. A positive Dix-Hallpike finding would involve a strong vertigo reaction in the supine position and often again as the patient is brought back to a sitting position. A hallmark of BPPV is fatigability, meaning that if the maneuver is performed a second time, the resulting vertigo is weaker than the first time.

The last portion of the ENG/VNG test battery is calorics, which involves putting cold and warm water (or air) into the ear canal and recording the resulting nystagmus. This test evaluates the integrity of the horizontal semicircular canal and the superior vestibular nerve (McCaslin, 2013). Calorics work by changing the temperature, and thus the density, of the endolymph in the inner ear. The change in density of the endolymph makes the density ratio between the cupula and endolymph change, thus displacing the cupula and activating neural pathways. These neural pathways initiate eye movements

via the vestibulo-ocular reflex, which are analyzed to interpret the results. Abnormal results present as a weakened nystagmus response, either unilaterally or bilaterally, or as a failure to suppress the nystagmus when asked to fixate on something during the testing procedure (McCaslin, 2013).

Rotary Chair

Rotary chair testing can be included within the vestibular test battery (Brandt & Strupp, 2005). During this test, a patient sits in a chair that rotates at various velocities and frequencies while his or her eye movements are tracked. Rotary chair testing is used to measure the gain of the VOR or the ratio between head movements and eye movements. Different frequencies from 0.001 to 1 Hz can be tested (Hain, 2018), unlike calorics that evaluate the VOR at the low frequency of 0.003 Hz (Brandt & Strupp, 2005). When the patient is being rotated at a constant speed, the induced nystagmus resolves after approximately 20 seconds and thus cannot be measured at this point. However, if the patient is stopped, another bout of nystagmus, called post-rotational nystagmus, is triggered and measured.

Rotary chair testing is useful for diagnosing bilateral vestibular failure. Because both labyrinths are activated simultaneously, the laterality of a unilateral dysfunction cannot always be determined by rotary chair alone (Brandt & Strupp, 2005).

Vestibular Evoked Myogenic Potential

Another test that evaluates a portion of the vestibular system is the vestibular evoked myogenic potential (VEMP). There are two types of VEMP: the cervical VEMP or cVEMP and the ocular VEMP or oVEMP. A VEMP is a muscular response that occurs due to stimulation of the vestibular organs and the vestibular portions of cranial

nerve VIII via an acoustic signal. Signals through air conduction activate afferent neurons of the saccule and signals through bone conduction activate afferent neurons of both the saccule and utricle (Rosengren, Welgampola, & Colebatch, 2010). When the acoustic signal is loud enough, vibrations of the endolymph are strong enough to stimulate the otoliths in addition to the cochlea.

Testing for VEMP uses electrodes to detect muscle activity. Because the vestibular system can influence other bodily systems, such as muscle groups, the VEMP response is evaluated by measuring responses from the ipsilateral sternocleidomastoid muscle (SCM). A sound that is loud enough will trigger relaxation of this muscle (Backous & Cloutier, 2017). These responses are referred to as a cervical VEMP, or cVEMP, and are useful to evaluate the saccule and inferior branch of the vestibular nerve. Another type of VEMP, the ocular VEMP or oVEMP, uses responses to acoustic stimuli measured from muscles around the eyes, specifically the inferior oblique extraocular muscle, and provides information about the utricle and the superior branch of the vestibular nerve (Backous & Cloutier, 2017).

Results from VEMP testing could help diagnose superior semicircular canal dehiscence (SSCD), in which thresholds that elicit a response will be produced at lower than expected levels, or patients with Meniere's disease (MD), in which thresholds will be elevated (Backous & Cloutier, 2017).

Posturography

To determine the contribution of the various systems responsible for balance, i.e. the vestibular, visual, and proprioceptive systems, a computerized posturography evaluation can be performed. Posturography testing is a combination of both static and

dynamic subtests. Computerized dynamic posturography tests evaluate a person's postural control system. This is done by measuring their response to a disturbance in their stance, whether applied or voluntary (Prieto, Myklebust, Hoffmann, Lovett, & Myklebust, 1996). Meanwhile, static posturography or postural steadiness measures the postural control system while a person remains static and is standing. These tests are measured by having the patient stand on a footplate while strapped into a harness in case of a fall (Judson & Galatioto, 2017). The footplate measures the patient's reactive movements to various changes in their environment.

One posturography subtest is the sensory organization test in which a patient is required to maintain balance under various conditions including with or without vision; standing on a flat, stable surface or standing on an unstable surface; and in static or dynamic conditions (Brandt & Strupp, 2005). The patient stands on the force platform, which is able to detect and track the "degree of sway or alignment around the patient's center of gravity" (Judson & Galatioto, 2017, p. 21). By manipulating these different conditions, the tester collects data about how the patient's center of pressure changes. This information is useful in rehabilitative settings in order to predict the direction a person would fall as well as monitor improvements and changes in stability and balance. The data are also useful in diagnosing the site of lesion or the type of vestibular dysfunction (Brandt & Strupp, 2005).

Posturography also includes the motor control test. In this test, the patient stands on the force platform and the surface on which the platform sits moves in both the forward and backward direction (Trueblood, Rivera, Lopez, Bentley, & Wubenhorst,

2018). With these movements, the force platform is able to detect how the patient reacts and their ability to recover in the case of unexpected shifts.

The third subtest of posturography is the adaptation test in which the force platform shifts at various angles. The patient is evaluated by their ability to adapt to the shifts and postural instability with minimal amounts of sway (Trueblood et al., 2018)

Video Head Impulse Test

The vHIT is a fairly new method of evaluation and is an adaptation of the head impulse test developed in 1988 by Halmagyi and Curthoys (Judson & Galatioto, 2017). While other vestibular diagnostic tests, such as portions of an ENG/VNG, can evaluate the functioning of the semicircular canals, the vHIT is the only test that can evaluate all six canals individually.

In addition to being able to individually evaluate each of the six semicircular canals, the vHIT also has several other advantages (MacDougall, Weber, McGarvie, Halmagyi, & Curthoys, 2009). Once a tester is proficient at the testing process, the vHIT is quick and can be performed on both adults and children. As long as there is access to an outlet and space for the testing procedure, the vHIT can be completed at bedside as it is portable with the use of a laptop to run the software.

The downfall of vHIT lies in user error, i.e. the ability of the tester to perform the test correctly, and the ability of the patient to maintain visual fixation (Judson & Galatioto, 2017). In a study of 1,358 head impulse traces, “72% had abnormal disruptive saccades, 44% had at least one artifact, and 42% were uninterpretable” (Mantokoudis et al., 2014, p. 39). Of the sample of head impulse traces, only about 42% were free of artifact or disruptive eye movements.

Testing Procedure and Normative Data

In the vHIT test procedure, the tester has the patient fixate on a point about a meter away. While the tester moves the patient's head in short, precise rotations, goggles track both the head velocity and the eye movements that accompany these head movements (MacDougall et al., 2009). The monocular video goggles track several things including overt saccades, covert saccades, and VOR gain, which is the ratio between eye velocity and head velocity. To track gain, the goggles have a camera and a mirror to reflect an image of the eye onto the camera, similar to goggles used for a VNG. The contrast between the pupil and the iris allows pupil movements to be detected. A gyroscope and accelerometer are included in the goggles for detection of head movement and velocity. With both the pupil tracking and head movement tracking, gain can be measured. Catch-up saccades are rapid corrective eye movements from one focal target to the next (Judson & Galatioto, 2017) and are detected by the camera in the goggles. Overt saccades can be observed by watching a patient's eyes as they occur after a head impulse, while covert saccades are corrective eye movements that cannot be observed without special equipment as they occur during the head impulse (Blödow, Pannasch, & Walther, 2013; Judson & Galatioto, 2017).

Because the semicircular canals function in pairs, the vHIT is performed in three sets of head impulses in order to evaluate each canal, resulting in a total of six head movements—one to evaluate each of the six semicircular canals. Of the six, two are motions to the left and right to test the lateral canals. Another two include motions forward and backward in the RALP plane to test the right anterior and left posterior canals. The last two motions are forward and backward in the LARP plane to test the left

anterior and right posterior canals. By testing all six motions for all six canals, peripheral vestibular lesions specific to the SSCs can be identified. Responses are divided into four types: normal gain values without the presence of saccades, normal gain with saccades, low gain without saccades, and low gain with saccades (Eza-Nuñez, Fariñas-Alvarez, & Perez-Fernandez, 2014). According to Eza-Nuñez et al. (2014), a peripheral vestibular pathology can only be diagnosed in the presence of both low gain and saccades. Normal gain values are expected to be around 1.0 (1.02 ± 0.07) up to age 70 but can range from 0.79-1.20 (Weber, 2017; Yang et al., 2016).

In addition to normative values for gain for the horizontal VOR in 50 participants 20-69 years of age on the Otometrics ICS Impulse system, Yang et al. (2016) also determined normative values for gain asymmetry and catch-up saccades. Gain asymmetry was calculated by the following formula:

$$GA = \text{the absolute value of } [(Gr - Gl)/(Gr + Gl)] \times 100\%$$

where GA was gain asymmetry, Gr was the right vHIT gain, and Gl ws the left vHIT gain. The average gain asymmetry was 2.39 ± 1.96% and catch-up saccades were measured in 49% of ears. No significant age effect was found between age groups (Yang et al., 2016). Likewise, McGarvie, MacDougall et al. (2015) found no effect of age on the VOR gain in healthy participants. Meanwhile, Guerra Jiménez and Pérez Fernández (2016) evaluated patients with vHIT, focusing on gain in the posterior semicircular canals. In patients with no vestibular disorder, a significant reduction in gain of the posterior semicircular canals was measured as an effect of age (Guerra Jiménez & Pérez Fernández, 2016). This finding might suggest the presence of ampullar degeneration due to age.

Bachmann, Sipos, Lavender, and Hunter (2018) collected normative data for the pediatric population from ages 4 to 12 (30 participants) using the Otometrics ICS Impulse system. After determining no significant differences amongst ages in the pediatric group, VOR gain was compared between the pediatric group and an adult group consisting of 11 healthy adults from ages 22 to 45. Overall, researchers found the children had a significantly higher mean VOR gain for the left lateral SCC condition and a significantly lower mean VOR gain for the left anterior and right posterior (LARP) SCCs (Bachmann et al., 2018) with means of 0.96, 0.80, and 0.83, respectively, in comparison with adult norms. In the right anterior and left posterior conditions, a large variability in VOR gain was measured, which was partially due to large pupil size in the pediatric group. Pupil diameter increases from 5-6 years to 11-13 years of age and then decreases into adulthood (Bachmann et al., 2018).

Clinical Application for Video Head Impulse Test

Measurement of VOR gain and catch-up saccades can be used when evaluating the vestibular system with vHIT. When the gain and number of saccades are combined, more accurate diagnoses of vestibular pathology can be made (Janky et al., 2018). Janky et al. (2018) compared vHIT results in the lateral conditions from participants with normal vestibular function (70 participants) to participants with unilateral or bilateral vestibular pathology (49 participants) using the Otometrics Impulse system. When comparing participants with a vestibular loss to normal controls, those with a pathology were more likely to have both abnormal gain and the presence of repeatable corrective saccades (42/66 ears), whereas none of the participants in the control group had the presence of both (0/70 ears). In comparison, low gain alone was seen in 3/66 ears of

those with vestibular loss and 1/70 ears in the normal controls. Corrective saccades alone were seen in 5/66 ears in the vestibular loss group and 5/70 ears in the normal controls (Janky et al., 2018).

Another use of vHIT has been for evaluation of patients with significant noise exposure. Yilmaz, Ila, Soylemez, and Ozdek (2018) used vHIT to evaluate the vestibular system in 36 males with noise-induced hearing loss due to working in the metal and steel industry for four or more years. A full vHIT battery including all six canals was used to determine if noise exposure could also cause damage to the vestibular system. When compared to the control group of 30 healthy men without hearing loss, the noise exposure group had a significantly higher rate of vestibular dysfunction as measured by canal deficit or a decrease in average gain in at least one canal. This finding suggested noise exposure could affect the functioning of the vestibular system (Yilmaz et al., 2018).

Other uses of vHIT have been described in the literature. For example, Pavlović et al. (2017) used vHIT to evaluate participants with multiple sclerosis. Participants who had been diagnosed with multiple sclerosis were tested with vHIT and received an MRI. Pavlović et al. (2017) found a significant relationship between reduced lateral canal gain bilaterally and the presence of a brainstem lesion ($p < .05$), indicating vHIT might be used to detect brainstem lesions in patients with multiple sclerosis.

With the varying degrees of severity and sites of lesion in vestibular pathologies, it is important to know what to include in a test battery to best evaluate the dysfunction. For example, both the vHIT and calorics testing evaluate the horizontal semicircular canals and together give complementary information for diagnostic purposes (Eza-Nuñez et al., 2014). Several studies have been conducted to explore the differences between

vHIT and calorics testing when evaluating patients with various vestibular pathologies. Burston, Mossman, Mossman, and Weatherall (2018) found evidence supporting the use of both calorics and vHIT when testing patients with vestibular symptoms lasting a month or more. Caloric testing was more sensitive in identifying unilateral vestibular hypofunction and vHIT was more sensitive in identifying those with bilateral vestibular hypofunction (Burston et al., 2018). The risk of a false negative was possible if either of the two tests was used alone. Park, Park, Kim, and Koo (2017) also discussed the benefits of using calorics and vHIT as complementary tasks in determining lateralization of a vestibular pathology since the two tests evaluate the horizontal semicircular canals at different frequencies. In testing patients with vestibular neuritis (Redondo-Martínez et al., 2016), Meniere's disease (Blödow et al., 2014; McGarvie, Curthoys, MacDougall, & Halmagyi, 2015; Rubin et al., 2018), and vestibular migraine, calorics and vHIT provided differing and complementary information in both adults and in children with vestibular symptoms (Khater & Afifi, 2016). Flowcharts for test protocols were provided by GN Otometrics for the diagnosis of peripheral vestibular disorders, BPPV, vestibular neuritis, and Meniere's disease (Boorazanes, Crumley-Welsh, & Young, 2015). These flowcharts gave guidelines on what test batteries should consist of to assess or diagnose these different disorders. For example, the recommended workflow for suspected Meniere's disease included case history, physical exam, hearing exam, vHIT or impulse testing, and VEMP with additional testing including electrocochleography and calorics to confirm a diagnosis.

Caffeine's Effect on the Body

A common instruction given to patients in preparation for many vestibular tests involves the abstinence of several things including tobacco, medications, especially those that affect or suppress the vestibular system, and caffeine. However, these instructions could vary from clinic to clinic with instructions ranging from avoiding caffeine for 72 hours prior to testing, 48 hours prior, 24 hours prior, no intake on the day of testing, or no changes to caffeine intake (Felipe et al., 2005).

Caffeine ("Caffeine: Drug information," 2018) begins to take effect on the body fairly quickly, approximately 30-60 minutes after ingestion. Its half-life elimination time or the time it takes for the body to expel half the amount of caffeine consumed is four to six hours for a healthy adult; this time varies based on medications, liver health, pregnancy, age, and body weight. As previously discussed, caffeine ("Caffeine," 2019) is a central nervous system stimulant that has the potential to affect or increase muscle twitches as well as voluntary activation of muscles or the level of neural drive to muscle during exercise (Gandevia, Allen, & McKenzie, 1995). This effect on muscle is seen more strongly in larger muscle groups such as muscles in the lower body (Timmins & Saunders, 2014). Other effects of caffeine include an increase in heart rate and blood pressure, a diuretic effect, and a potential interference with calcium absorption of the body's cells. There is evidence that daily caffeine use results in adaptation or tolerance, resulting in weaker physiological effects of the substance (Lara, Ruiz-Moreno, Salinero, & Coso, 2019). However, with the potential for these physiological effects to affect the vestibular system and how it reacts to various evaluations, it is important for clinicians to determine the necessity of asking their patients to abstain from caffeine prior to testing.

Caffeine's Effect on the Vestibular System

Felipe et al. (2005) compared results from a series of tests involving an examination with Frenzel lenses, an ocular motricity test, and caloric testing with and without interruption of caffeine intake 24 hours prior to testing. Participants (N = 19) were females between the ages of 21 and 76 who regularly consumed a moderate (200-300 mg/day) amount of coffee. Using the participants as their own control group, no significant differences were found between the two testing conditions.

Similar to Felipe et al. (2005), McNerney et al. (2014b) tested healthy participants with and without caffeine cessation. The authors performed the sensory organization test on 30 healthy adults with no history of vestibular disorders. McNerney et al. found no difference in test results between the two conditions of having had approximately 300 mg of caffeine prior to testing and having abstained from caffeine for 24 hours prior to testing. McNerney, Coad, and Burkard (2014a) found no effect of caffeine consumption (approximately 300 mg) on the results of calorics testing and cVEMP testing in young, healthy adults. Supporting these findings, Souza, Costa, and Menezes (2018) conducted a meta-analysis regarding caffeine consumption and the outcome of VEMP testing, and also noted no effect of caffeine on cVEMP.

In a literature review, Ledesma, Barreto, and Bahmad (2014) found no definitive conclusion to the question of whether or not patients should abstain from caffeine prior to vestibular testing. After reviewing 10 articles related to the effects of caffeine on vestibular testing, the researchers concluded the decision to instruct patients to abstain from caffeine should be based on clinical experience until more conclusive research could be performed on this topic (Ledesma et al., 2014). Of the 10 articles reviewed by

Ledesma et al., five articles addressed the topic of caffeine's effect on vestibular disorders, three of which involved Meniere's disease specifically. Rauch (2010) indicated that in normal circumstances, intake of fluids such as caffeine and alcohol would have no effect on the production of fluid (endolymph and perilymph) in the inner ear. However, the imbalance of the systems that regulate fluid production in Meniere's disease would cause the production of endolymph and perilymph to be affected (Rauch, 2010). Knox and McPherson (1997) discussed caffeine restriction in addressing Meniere's disease but did not give justification of the physiological effects of caffeine on the vestibular system. Luxford, Berliner, Lee, and Luxford (2013) conducted a retrospective study to explore the effect of adherence to a sodium-controlled and a caffeine-abstained diet in patients with Meniere's disease. Patients reported fewer crises but not at a level that was statistically significant. While caffeine is a natural diuretic and diuretics are often prescribed to those with Meniere's disease, its stimulant properties have the potential to make Meniere's disease symptoms worse (Ledesma et al., 2014). Overall, based on their review, Ledesma et al. were unable to determine a definitive answer regarding the effect of caffeine on vestibular testing.

McNerney, Coad, and Burkard (2018) tested 30 young, healthy adults and the effect of caffeine (approximately 300 mg) on the results of rotary chair and oculomotor testing. An effect of caffeine was seen on vertical saccades, horizontal saccades, and optokinetics. When the researchers analyzed the data with stratified groups based on typical caffeine intake, there was a significant effect of caffeine on the no/low caffeine intake group (0-183 mg of caffeine per day), whereas no significant effect was seen on the moderate/high caffeine intake group (231-623 mg of caffeine per day), suggesting

patients who regularly ingested caffeine did not need to abstain from caffeine prior to oculomotor or rotary chair testing (McNerney et al., 2018).

Caffeine's Effect on the Auditory System

In research by Dixit, Vaney, and Tandon (2006), an effect of caffeine was found during auditory evoked potentials testing. The participants, 40 healthy adults, abstained from caffeine for 12 hours and then consumed caffeine in proportion to their body weight (3 mg/kg). Testing was done before and 40 minutes after consumption of caffeine with participants acting as their own controls. Auditory brainstem response testing revealed decreases in the absolute latencies of wave IV and V, the interpeak latencies of wave I-V, as well as an enhancement of the amplitude of wave V. In the middle latency response testing and slow vertex response testing, latencies were also decreased. These results suggested caffeine causes an improvement in the nerve conduction and transmission of signals through the peripheral nerve pathways and central auditory brainstem pathways (Dixit et al., 2006), consistent with the stimulatory properties of caffeine.

Caffeine's Effect on Eye Movements

Many vestibular tests involve observing eye movements to evaluate the vestibular system including the vHIT. Therefore, understanding how caffeine affects eye movements in addition to how it affects the vestibular system is important. Connell et al. (2017) observed caffeine's effect on oculomotor control and visual perception by looking at saccades, smooth pursuit, and optokinetic nystagmus (OKN). Participants ingested 5 mg of caffeine per kg of body mass and were tested over a three-hour span. In 13 healthy adults, caffeine had a significant effect ($p < .05$) on the peak saccade velocity, which

increased when compared to a placebo group. In addition to peak saccade velocity, caffeine also had a significant effect on both the peak velocity and the amplitude of the quick phase of OKN. Both the slow phase of the OKN and smooth pursuit were unaffected by caffeine (Connell et al., 2017).

Similar to Connell et al. (2017), Wilhelmus et al. (2016) also found an effect of caffeine on certain eye movements. The researchers tested the effect of 60 mg of caffeine on attention in 82 healthy adult participants. In looking at attention, Wilhelmus et al. observed caffeine's effect on saccadic eye movements. The researchers found caffeine significantly increased peak velocity and reaction time of saccadic eye movements at 70 and 120 minutes after administration. There was no significant effect of caffeine on eye movements at 180 and 300 minutes after administration and no effect at any time on the percentage of inaccurate saccadic eye movements (Wilhelmus et al., 2016). Smith, Brice, Nash, Rich, and Nutt (2003) observed the effect of simultaneous use of caffeine and clonidine, which is a sedative and antihypertensive drug that can influence central noradrenaline, on different physiological functions including saccadic eye movements. The caffeine/decaffeinated conditions were executed using decaffeinated coffee for all participants. In the caffeinated conditions, a caffeine solution based on body weight (1.5 mg/kg) was added to the decaffeinated coffee and in the decaffeinated condition, a placebo in the form of water was added to the decaffeinated coffee. In comparing the clonidine/caffeine condition to the clonidine/decaffeinated condition, a lack of caffeine resulted in slower peak acceleration and peak velocity (Smith et al., 2003).

Summary

Abstinence from caffeine intake has long been included in the instructions for patients preparing for vestibular testing. While the effect of caffeine on the body would lead clinicians to believe an effect would be present in vestibular test results, there was inconsistency in the literature regarding caffeine's effect. While caffeine seemed to affect the results of a portion of the VNG test battery, it was determined these effects were not statistically significant in participants who were moderate/high caffeine consumers but rather only in those who were no/low caffeine consumers (McNerney et al., 2018). These findings suggested it was important to know or control for a participant's typical daily caffeine intake when evaluating caffeine's effect on various test results in a research study. Essentially no other significant effects of caffeine on vestibular testing were found in the literature.

In completing this literature review, no research was found addressing whether or not caffeine had an effect on the vHIT results on either normal participants or those with vestibular dysfunction. With caffeine's effects on muscular twitches and response time paired with the vHIT's evaluation of head and eye movements, research is necessary to determine if caffeine affects vHIT results for healthy, normal participants.

CHAPTER III

METHODOLOGY

The purpose of this study was to evaluate the effect of caffeine consumption on the results of the video head impulse test (vHIT) for participants with no known vestibular abnormalities. The testing was performed at the University of Northern Colorado using the Otometrics ICS Impulse system. The results of testing were compared at two points in time: (a) after each participant had abstained from caffeine intake for at least 24 hours prior to testing and (b) approximately one hour after intake of either caffeinated or decaffeinated coffee. Differences in the two conditions were compared across two groups: one that consumed caffeinated coffee and one that consumed decaffeinated coffee. The differences in VOR gain were compared across testing conditions for each group and the presence of overt saccades and covert saccades was observed. This research protocol was approved by the Institutional Review Board at the University of Northern Colorado (see Appendix A).

Participants

Adult participants age 22 to 65 years were recruited for this study with a criterion allowing those from 20-69 years of age based on norms provided by Yang et al. (2016). A consent form was read and signed by each participant prior to participation (see Appendix B). Additional inclusion criteria included a negative history of vestibular pathology, a negative history of neck injury, and eyesight adequate for seeing a one-inch dot from approximately one meter away. Those who were pregnant, smoked tobacco, or

had a positive history of liver pathology were excluded due to a difference in how the body processes caffeine ("Caffeine: Drug information," 2018) in these populations.

Testing Timeline

After the participants read and signed the consent form, testing began. First, the baseline test in the caffeine-abstained condition was performed in a designated testing room, which took approximately 15 minutes. Next, the participant was given a 12 oz cup of coffee. The coffee was poured by an assistant behind a barrier to keep the type of coffee unknown to the tester and the participants. The assistant was aware of which participants were randomly assigned to each group (caffeinated vs. decaffeinated) and could thus select the appropriate coffee. The participants were instructed to start drinking their coffee after the first test was performed. They were allowed to add cream and/or sugar to their coffee. Once participants were halfway done with their coffee, a timer was set for 45 minutes to allow the caffeine to be absorbed into their bloodstreams and participants continued to finish the remainder of their coffee. Participants were allowed to move about or to have something to work on during the waiting period.

Once the participants had waited the allotted time after drinking their coffee, the second test was performed. A post coffee consumption test was performed in the same manner as the baseline test and is described in detail in the following sections.

Caffeinated and Decaffeinated Coffee

Participants were separated into two groups based on the type of coffee consumed. Group 1 consumed caffeinated coffee. The coffee used was Starbucks Blonde Roast coffee. One 12 oz cup is estimated to contain 270 mg of caffeine. Group 2

consumed decaffeinated coffee. The brand used was Starbucks Blonde Roast decaffeinated coffee, which is estimated to contain 20 mg of caffeine per 12 oz cup.

Video Head Impulse Test Equipment

The Otometrics ICS Impulse system was used for this study. The Otometrics system allows for administering the vHIT as well as analysis of the test results. This equipment includes the program software (version 2013.10.02) and the ICS Impulse goggles. The software was used on a Lenovo laptop running on Windows 7. A disposable face cushion was given to each participant to be used with the vHIT goggles throughout testing.

Video Head Impulse Test Procedure

The participants were randomly assigned to group 1— the group that consumed caffeinated coffee or group 2—the group that consumed decaffeinated coffee. This was completed by a research assistant who assigned participant numbers to cards that either had “caffeine” or “decaf” written on them by randomly selecting a card from a stack. The vHIT testing began with the caffeine-abstained condition for each participant. The participants had been instructed to suspend any form of caffeine consumption for 24 hours before testing, which was verbally confirmed prior to testing.

Each participant was entered into the Otometrics ICS Impulse system. They were seated facing a wall one meter away. The test administrator placed the goggles on the participant’s head and tightened the straps to ensure the goggles did not slip during the testing procedures.

Once the participant was seated one meter away from the wall with a fixation dot placed on the wall in front of them at eye level, calibration was completed. A camera

built into the vHIT goggles was oriented to record the participant's eye and the test administrator was able to select the location of the pupil on the computer screen. Once the pupil was located and selected by the test administrator in the software, the camera tracked the participant's eye movements. To calibrate the equipment, the participant was asked to follow a laser point emitted from the front of the goggles on the wall in front of them as it jumped to the left and right of the fixation dot. The testing software ended this process once an acceptable calibration had been obtained.

After calibration of the eye movements, testing in the lateral condition began. The participant faced forward and was instructed to look at the fixation dot continuously throughout the testing procedure. The test administrator placed her hands on the participant's head, making sure not to touch the goggle straps. The tester moved the participant's head in small, swift movements approximately 10-20° to the left and right in random order until 20 accepted recordings to each side were collected as was recommended for clinical use of the vHIT. A recording was accepted if the movement of the head was within a certain range of speed and degrees. Recordings were rejected if they were too slow or if the head was moved too far in the direction it was being turned.

Data Analysis

The Otometrics ICS provided information about VOR gain (ratio of eye velocity to head velocity), peak velocity of head movement, number of overt and covert saccades, number of rejected samples, and asymmetry of results. Gain values were measured for two groups (caffeinated coffee and decaffeinated coffee) across two conditions (pre-coffee consumption and post-coffee consumption). Each ear was treated as a separate data point in order to avoid averaging each participant's left and right ear gain values.

This decision was made to account for any potential differences in gain between the left and right ears within each participant and to account for potential test administration differences when making head movements to the left or to the right. The data were organized in a Microsoft Excel spreadsheet. An independent-samples *t*-test (IBM SPSS Version 25) compared pre and post coffee consumption difference values for the two groups. Difference values were calculated by subtracting pre-coffee gain values from post-coffee gain values. A second independent samples *t*-test was completed to compare the absolute values of pre- and post-coffee consumption difference values for the two groups. In addition, a nonparametric Mann-Whitney U test was performed to assess the difference between groups with respect to number of overt and covert saccades recorded.

CHAPTER IV

RESULTS

Sample Characteristics

Nineteen adults from 22 to 65 years of age were recruited for this study using flyers and email as recruitment methods. All participants were screened to ensure they met this study's eligibility criteria. The mean age of the 19 participants was 30. Of the participants recruited, 14 (73.68%) were female and five (26.32%) were male.

As discussed below, one participant was removed from the data pool. After the removal of this participant, the mean age of the remaining 18 participants was 30.33 with 13 females (72.22%) and 5 males (27.78%).

Gain Values

Table 1 shows the distribution of gain values. A full chart of all gain values can be found in Appendix C. Gain values ranged from 0.77 to 1.11, with a mean gain value of 0.97. Only one gain value changed from the normal range (0.9) in the pre-coffee condition to the abnormal range (0.77) in the post-coffee condition. However, after completion of the study, it was discovered the participant whose gain value fell into the abnormal range (Participant 9) had a history of eye surgery due to her medial rectus muscle on the right side not being tight enough. Participant 9 subsequently reported that due to the surgery, her right eye now turns in slightly, which could be exacerbated when she was fatigued. Due to the possibility that this interfered with the movement of the eye or the measurement of this movement, all data from this participant were removed from

the data pool. After the removal of this participant from the data pool, gain values ranged from .82 to 1.11 with a mean gain of 0.97.

Table 1

Distribution of Gain Values by Group

Group		Test	Minimum	Maximum	Range	*M*	*SD*
1 (Caffeine)	*N* =18 (ears)	Before	0.82	1.11	0.29	0.97	0.0679
		After	0.83	1.11	0.28	0.96	0.0682
2 (Decaf)	N=18 (ears)	Before	0.87	1.08	0.21	0.99	0.0553
		After	0.92	1.09	0.17	0.99	0.0420

Caffeine Versus Decaffeinated Gain Value Comparison

The goal of this study was to determine if there was a significant difference in gain values between video head impulse test results before and after caffeine consumption. An independent-samples *t*-test completed comparing pre- and post-coffee consumption difference values between groups indicated no significant difference in the change in gain values between group 1 and group 2 ($t(25.698) = .028$, $p = .978$). These statistics are summarized in Table 2. The *t*-test was also completed with all 19 participants including data from the participant who had reported a history of eye surgery. Neither test showed a significant difference between groups. The average gain values for various conditions are displayed in Figure 2 including all tests as well as the left and right conditions separated by group. Individual difference values for each ear can be observed in Figure 3.

Table 2

Results of T-Test for Equality of Means

		Levene's test for Equality of Variances		*t*-test for Equality of Means						
		F	Sig.	*t*	*df*	Sig. (2-tailed)	Mean difference	Std. Error difference	95% CI lower	upper
Difference Values	Equal Variances Assumed	8.254	.007	.028	34	.977	.001	.020	-.039	.040
	Equal Variances Not Assumed			.028	25.698	.978	.001	.020	-.040	.041

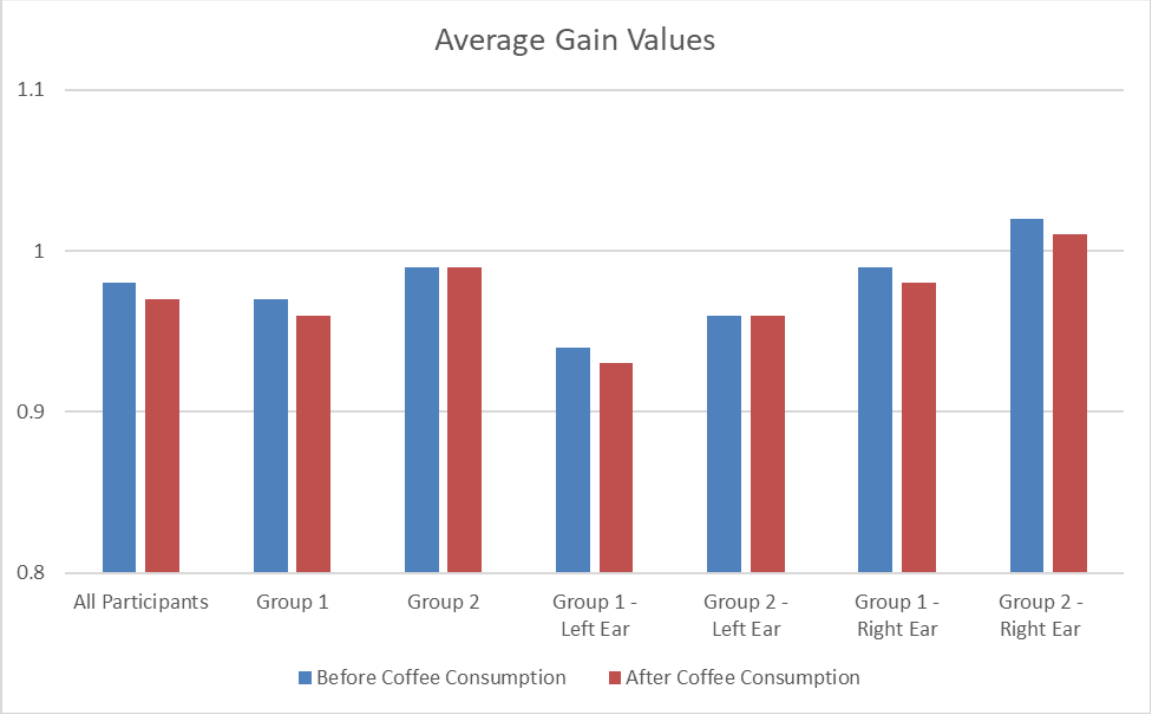

Figure 2. Average gain values, separated by pre-coffee testing in blue, and post-coffee testing in red.

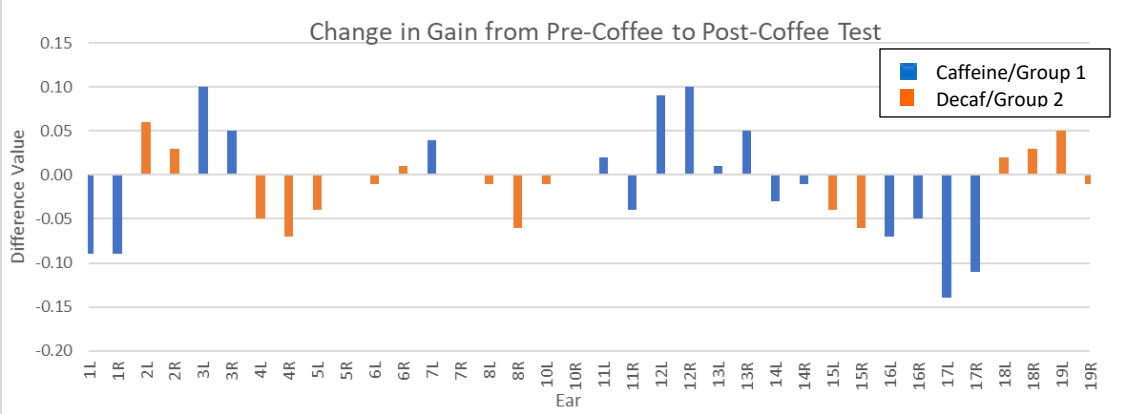

Figure 3. Difference values by ear. Ears without a bar had difference values of 0, and their group can be determined by the participant's paired ear.

A *t*-test completed comparing the absolute values of the pre- and post-coffee consumption difference values between groups indicated a significant difference in the change in gain values between group 1 and group 2 ($t(27.435) = 2.751$, $p = .01$). This second *t*-test was completed using the absolute value of the VOR gain difference values to determine if there was a significant difference in overall changes in gain between group regardless of the direction of change. It should be noted that for both *t*-tests, the data set did not meet the assumption of independent observation due to the fact that participants were represented twice as a left and a right ear. The results of this *t*-test are displayed in Table 3 below and boxplots indicating the spread of gain difference values are shown in Figure 4.

Table 3

Results of T-Test for Equality of Means Using Absolute Values

		Levene's test for Equality of Variances		*t*-test for Equality of Means						
		F	Sig.	*t*	*df*	Sig. (2-tailed)	Mean difference	Std. Error difference	95% CI lower	95% CI upper
Difference Values	Equal Variances Assumed	6.809	0.013	2.751	34	0.009	0.03	0.01	0.008	0.052
	Equal Variances Not Assumed			2.751	27.435	0.010	0.03	0.01	0.008	0.052

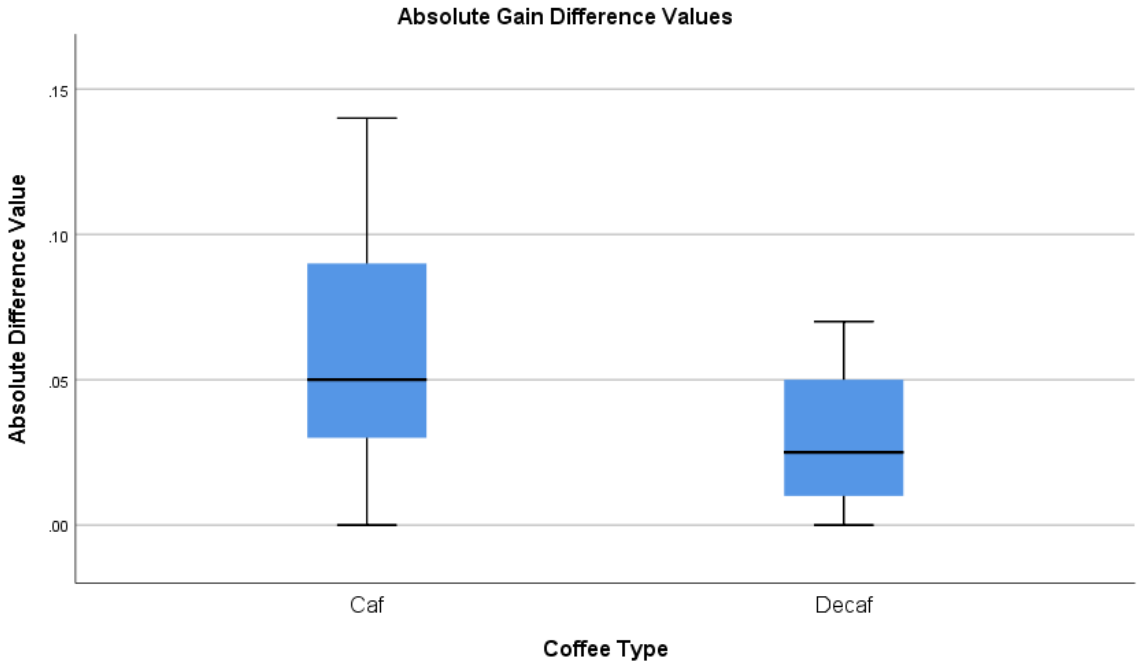

Figure 4. Boxplot showing the spread of difference values between group 1 (Caf) and group 2 (Decaf). The absolute value of the post-coffee test minus the pre-coffee test was used.

Because of a difference noted between average gain values of the left and right ears, separate *t*-tests comparing difference values for pre- and post-coffee consumption VOR gain between group 1 and group 2 were completed on left ears and right ears

separately using the absolute values of the difference values. These *t*-tests did not show statistical significance (left ears: $t(11.22) = 2.10$, $p = 0.059$; right ears: $t(14.58) = 1.70$, $p = 0.110$). Therefore, when considering left and right ears independently, there was no difference in the variability of VOR gain values from pre- to post-coffee consumption when comparing the two groups.

Additional Video Head Impulse Test Results

In addition to VOR gain results, other results included saccade counts for both overt and covert saccades, asymmetry between left and right gain values, and the number of rejected gain collections.

Overt and Covert Saccades

Overt and covert saccades were recorded for observational purposes. The presence of saccades was seen in both group 1 and group 2. Eight of the 18 participants had either overt or covert saccades (44.44%). Of these eight participants with saccades, three were in group 1 with caffeinated coffee and five were in group 2 with decaffeinated coffee.

Four of the eight participants with saccades had saccades in both the pre-coffee consumption condition and the post-coffee consumption conditions, two had saccades only in the post-coffee consumption condition, and two had saccades only in the pre-coffee consumption condition (see Figure 5).

Of the four participants with saccades both before and after coffee consumption, two were in group 1 and two were in group 2. Both participants with saccades in only the post-coffee consumption condition were in group 2. Of the two with saccades in only the

pre-coffee consumption condition, one was in group 1 and one was in group 2. A breakdown of the presence of saccades by group is shown in Figures 6 and 7.

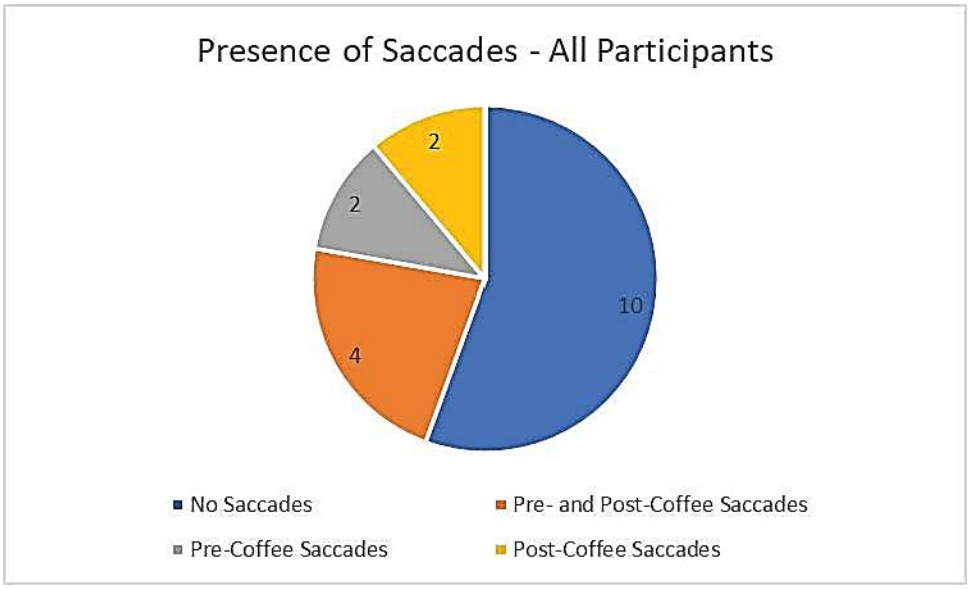

Figure 5. Chart showing the relative presence of saccades in all participants.

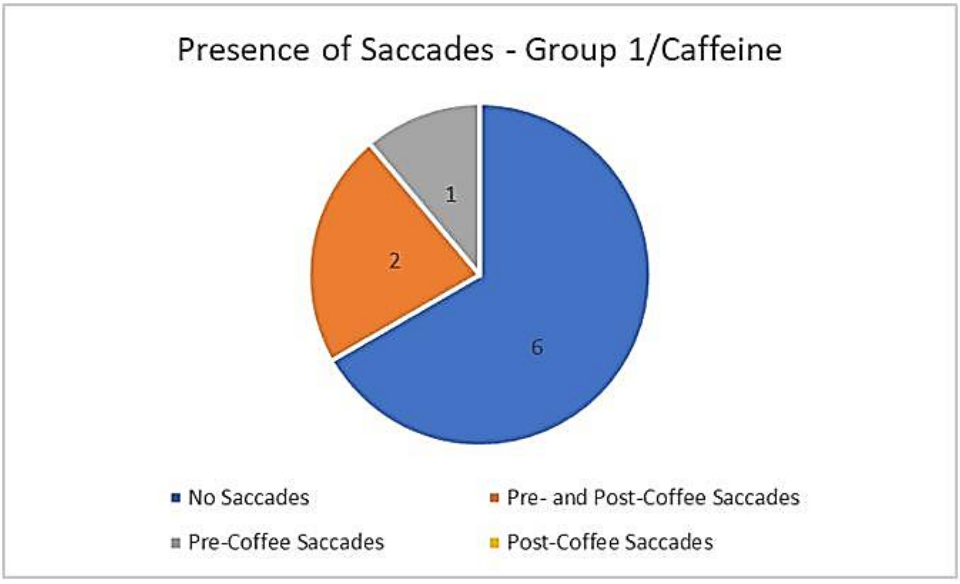

Figure 6. Chart showing the relative presence of saccades in group 1.

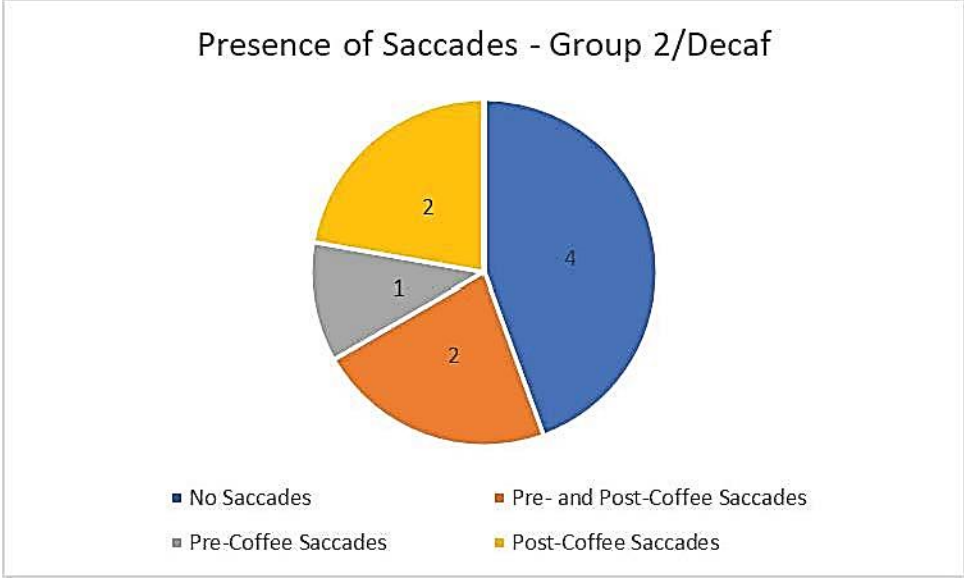

Figure 7. Chart showing the relative presence of saccades in group 2.

Figures 8, 9, and 10 show examples of saccades measured during data collection. Figure 8 shows vHIT gain collection without the present of any measured saccades. Figure 9 shows an example of a vHIT gain with the presence of overt saccades. Figure 10 shows a vHIT gain collection with the presence of covert saccades. A post hoc nonparametric test was performed to determine if the number of overt and covert saccades was significantly different between groups. A Mann-Whitney U test for two independent samples did not show a statistical significance of this trend for the presence of overt ($U = 175.5$, $n_1 = 20$, $n_2 = 18$, $p = .873$), covert ($U = 177$, $n_1 = 20$, $n_2 = 18$, $p = .869$), or total saccades ($U = 168.5$, $n_1 = 20$, $n_2 = 18$, $p = .697$) between the two groups.

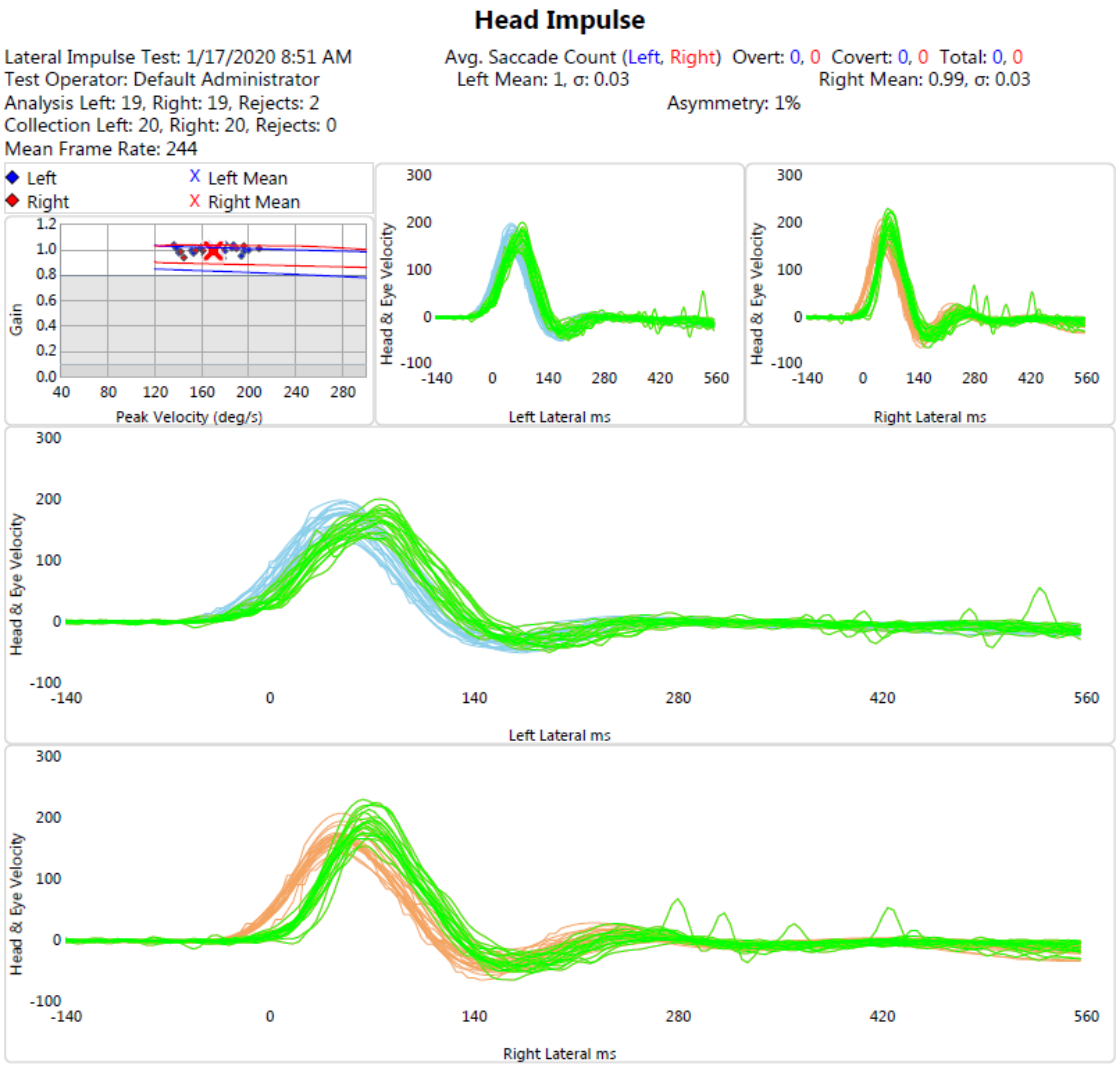

Figure 8. Example of video head impulse test recordings with no measured overt or covert saccades.

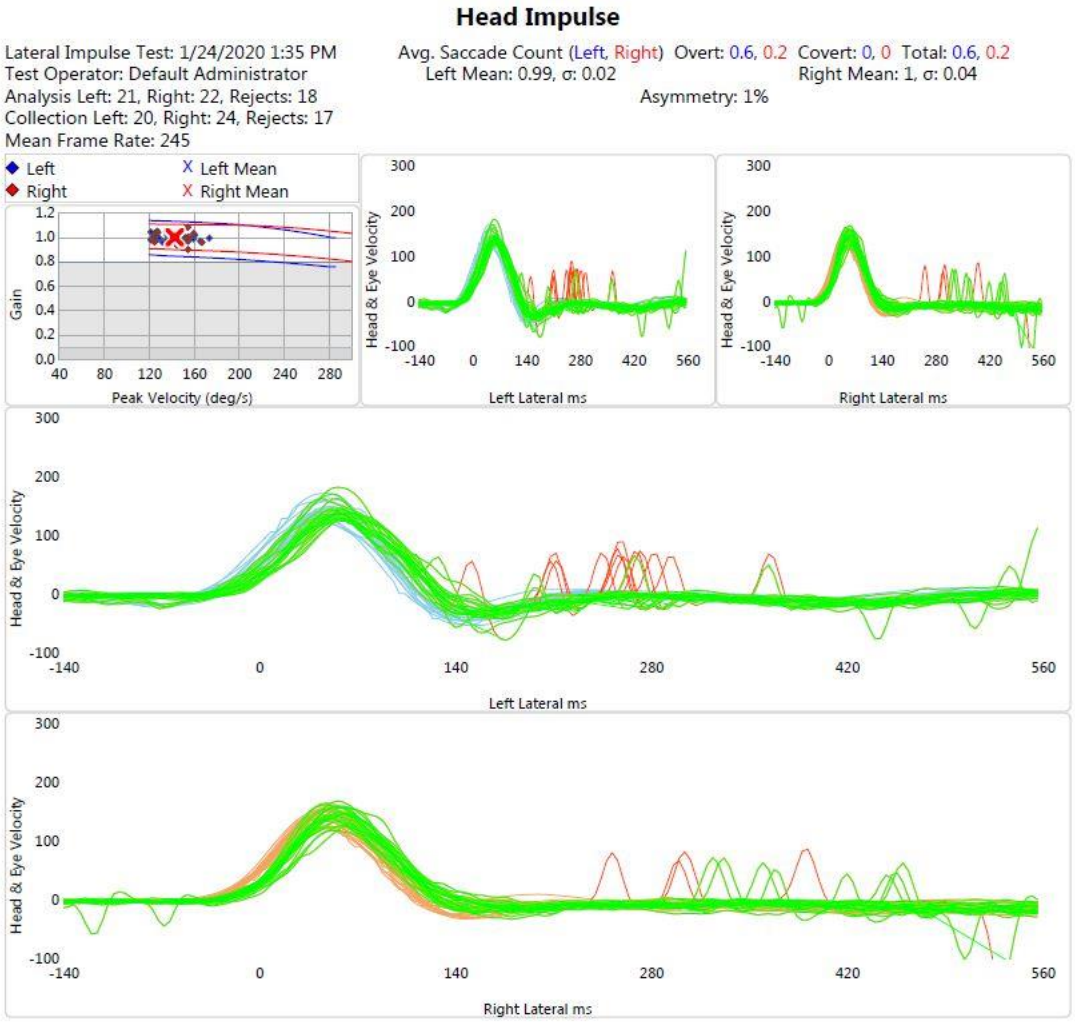

Figure 9. Example of video head impulse test recordings with overt saccades measured as shown by darker red lines.

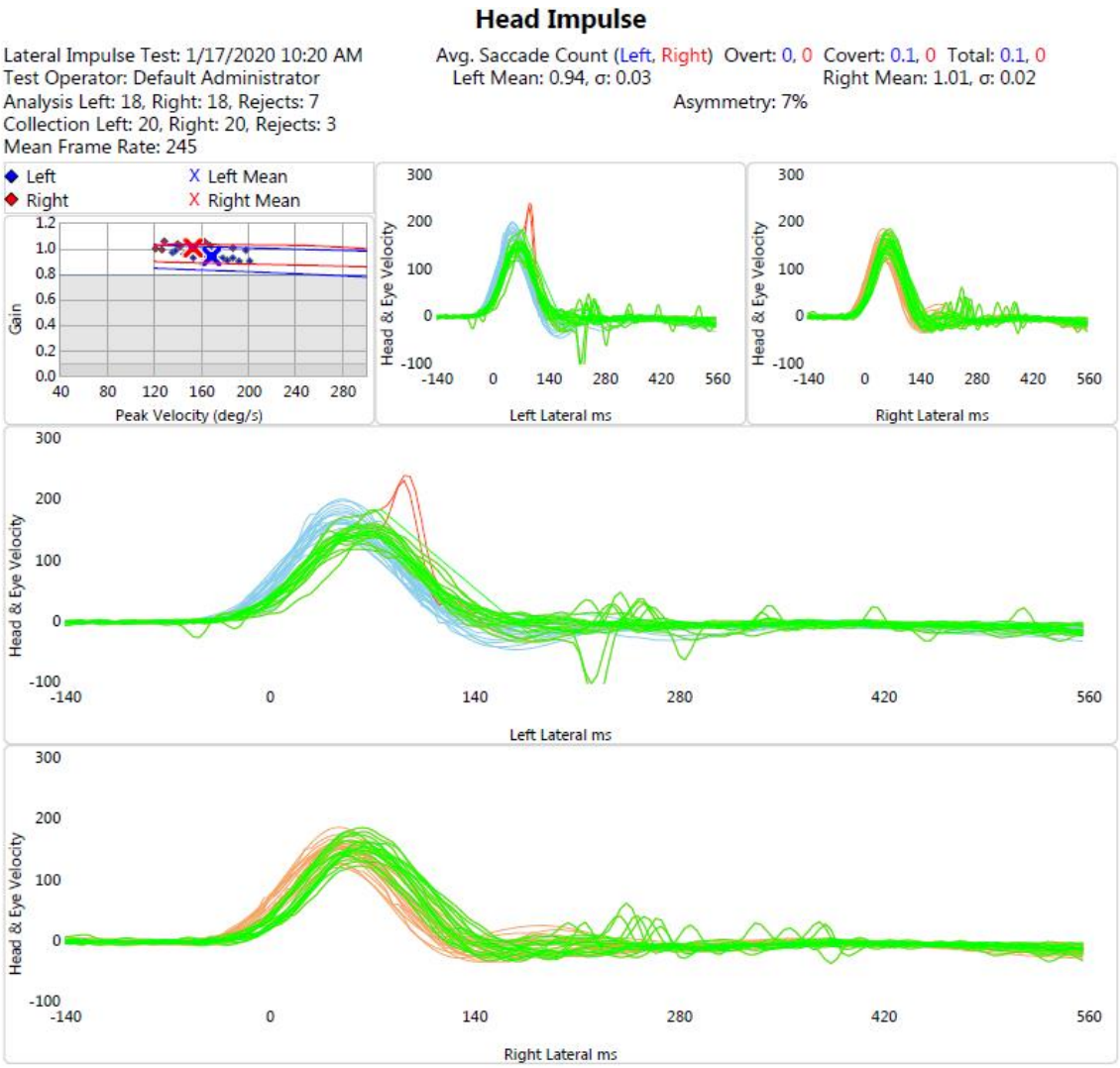

Figure 10. Example of video head impulse test recordings with covert saccades measured as shown by darker red lines in the left ear gain measurements.

Gain Asymmetry, Rejected Collections, and Peak Velocity

Based on norms established by Yang et al. (2016), the cutoff for abnormal gain asymmetry between left and right VOR gain values was greater than 8%. Six of the 18 participants had a gain asymmetry of greater than 8%. Four of those eight participants

showed asymmetry both before and after coffee consumption. Two participants showed gain asymmetry only before coffee consumption. A distribution of gain asymmetry between left and right VOR gain values is displayed in Table 4.

Table 4

Distribution of Gain Asymmetry by Group

Group		Test	Minimum	Maximum	*M*	*SD*
1 (Caffeine)	*N*=18 (ears)	Before	2%	15%	8%	4.72%
		After	2%	11%	7%	3.43%
2 (Decaf)	*N*=18 (ears)	Before	1%	12%	6%	4.23%
		After	2%	9%	5%	2.67%

To complete a vHIT examination, 20 collections were obtained in each condition. If head movements were too slow or did not fall within the desired range of movement, they were considered a rejection. Rejected trials ranged from 0 to 120 rejects with a mean of 25.36 rejected trials and a standard deviation of 31.25.

Peak head velocity referred to the speed at which the head was turned in degrees per second. The range should fall between 150-200°/s (Yang et al., 2016). The distribution of peak velocity by group is displayed in Table 5.

Table 5

Distribution of Peak Head Velocity by Group

Group		Test	Minimum	Maximum	*M*	*SD*
1 (Caffeine)	*N*=18 (ears)	Before	180	220	202.22	11.66
		After	150	220	195.00	17.24
2 (Decaf)	*N*=18 (ears)	Before	150	240	191.67	22.82
		After	150	220	182.78	18.09

Summary

The results of the first *t*-test showed no effect of the consumption of caffeine on the results of the vHIT when considering VOR gain difference values. No significant difference between the caffeine-abstained results and the post-consumption results was found in either group 1, which was given caffeinated coffee, or group 2, which was given decaffeinated coffee.

When the *t*-test was repeated using the absolute values of the difference values, the results showed a significant difference between group 1 and group 2; group 1 had significantly larger overall changes in VOR gain values from the caffeine-abstained results and post-consumption results. These results indicated more variability of difference values in group 1. However, the direction of the variability was sometimes positive and sometimes negative for post-coffee minus pre-coffee conditions as indicated by the nonsignificant results of the *t*-test that did not use absolute values.

In addition, the number of overt and covert saccades observed for each group was recorded. In general, there were few saccades for either group and the number of saccades for the two groups was not significantly different.

CHAPTER V

DISCUSSION

A common instruction for patients in clinical settings has been to avoid caffeine consumption prior to vestibular evaluation due to the suspected effect caffeine has on vestibular function. While this effect has not been shown in much of the current literature, uncertainty remains about what recommendations should be given to patients. To determine if this instruction was necessary, the purpose of this study was to determine what effect, if any, the consumption of caffeine had on the results of the vHIT, specifically gain measurements and the number of overt and covert catch-up saccades. This knowledge would allow those performing vHIT clinically to properly instruct their patients in how to prepare for the exam and avoid potential confounding factors.

Caffeine Consumption and Vestibular Testing

The current study's results showed a significant difference in the change in vHIT gain values before and after caffeine consumption when comparing a group that consumed caffeinated coffee and a group that consumed decaffeinated coffee when using the absolute value of the difference values. These results showed a greater variability between gain values in the pre-coffee condition versus post-coffee condition in group 1 when compared to those in group 2. However, because absolute values were used, these results did not show whether that variability had a consistent direction. If there was a significant increase or decrease in gain values in group 1, that significance would have been shown by the *t*-test performed without using absolute values. Because this *t*-test did

not show a statistical significance, a directional change in VOR gain could not be assumed.

Although there was a greater variability in changes in VOR gain seen in group 1 with the exception of results from one participant who had a history of eye surgery, none of the changes in VOR gain values for either group were clinically significant or put participants' gain values into the abnormal range, i.e., all of the participants would have been classified as having normal test results in a clinical setting regardless of coffee consumption. The largest change in gain for group 1 was 0.14 and the largest change for group 2 was 0.07.

The statistically significant results found in the current study deviated slightly from results found in several other studies in which researchers tried to determine an effect of caffeine on vestibular tests. Both Felipe et al. (2005), who evaluated the effect of caffeine on a series of tests involving an examination with Frenzel lenses (an ocular motricity test) and caloric testing, and McNerney et al. (2014b), who evaluated caffeine's effect on the sensory organization test, found no significant differences in tests with and without caffeine consumption. Additionally, McNerney et al. (2014a) found no effect of caffeine consumption on caloric testing and cVEMP. As in the current study, these studies involved healthy adults without a history of vestibular pathology. Results obtained in this study align with the normative data obtained by Yang et al. (2016) and Bachmann et al. (2018). Although those given caffeine showed a significantly greater change in VOR gain values and because that change was not seen in a consistent direction and post-coffee gain values were not in the abnormal range, there was still no strong evidence to support the need to abstain from caffeine prior to vHIT. Therefore,

the results of this study, along with other reports in the literature regarding vestibular test measures, suggested abstaining from caffeine consumption prior to some vestibular assessments, including vHIT testing, might not be necessary (see Table 6).

Table 6

Summary of Literature

Researchers	*N*	Mg of Caffeine	Vestibular Evaluation	Effect of Caffeine
Current study	18	270 mg	vHIT	A larger change in gain was observed in the group given caffeine when compared to the group given decaffeinated coffee. This change was not in a consistent direction (increase vs. decrease in gain).
Felipe et al. (2005)	19	200-300 mg (not controlled)	Series of tests (with Frenzel lenses, ocular motricity test, and calorics)	None
McNerney et al. (2014b	30	300 mg	Sensory organization test	None
McNerney et al. (2014a)	30	300 mg	Calorics, cVEMP	None
McNerney et al. (2018)	30	300 mg	Rotary chair, oculomotor testing	Vertical saccades and horizontal saccades (shorter duration and higher eye velocity), and optokinetics (higher eye velocity). When the researchers stratified the data based on caffeine intake, an effect of caffeine was only seen in those who were no/low caffeine consumers

While the initial results from the current study suggested the instruction to abstain from caffeine might not be necessary prior to performing the vHIT due to the small sample size, in order to generalize the findings, it would help if the findings could be replicated with a larger sample size.

Caffeine Consumption and Saccades

As previously discussed, caffeine ("Caffeine," 2019) is a central nervous system stimulant that has the potential to affect or increase muscle twitches, as well as voluntary activation of muscles, or the level of neural drive to muscle during exercise (Gandevia et al., 1995). With this in mind, it might be anticipated that overt and covert saccades would increase following caffeine consumption. Saccades are rapid corrective eye movements from one focal target to the next (Judson & Galatioto, 2017) and would likely be affected by increased muscle twitch activity.

While other researchers did not show significant effects of caffeine (Felipe et al., 2005; McNerney et al., 2014a, 2014b), McNerney et al. (2018) saw an effect on rotary chair and oculomotor test results. These effects were seen in vertical saccades, horizontal saccades, and optokinetics. These findings were interesting when considering the current study as saccades were part of what was measured when performing vHIT and determining vestibular dysfunction. However, it should be noted the types of saccades studied by McNerney et al. (2018) and the current study were different—the type of saccades observed in the current study were involuntary and occurred as a result of the head movement, while McNerney et al. (2018) studied saccades that were voluntary as the participants followed a laser point as it made small jumps horizontally and vertically.

An interesting observation in the current study was the prevalence of saccades in each group. Those who were in group 2, which was given decaffeinated coffee, had more saccades overall and more saccades in the post-coffee condition than those in group 1. Five participants had saccades in group 2 with four of those five having saccades in the post-coffee condition. In comparison, only three participants in group 1 had saccades with two of those three having saccades in the post-coffee condition. These data suggested those who regularly consumed caffeine might have a higher rate of saccades if they were asked to abstain from coffee prior to vHIT testing. McNerney et al. (2018) also found caffeine had an effect on saccades in those who were low or no caffeine consumers. These data from the current study and from McNerney et al. (2018) suggested that deviation from the norm, i.e., those who normally consumed caffeine abstaining from it or those who did not normally consume caffeine drinking, might be what had the greatest effect on saccadic eye movements. However, a Mann-Whitney U test for two independent samples completed on the saccade data from the current study did not show statistical significance of this trend for the presence of overt ($U = 175.5$, $n_1 = 20$, $n_2 = 18$, $p = 0.873$), covert ($U = 177$, $n_1 = 20$, $n_2 = 18$, $p = 0.869$), or total saccades ($U = 168.5$, $n_1 = 20$, $n_2 = 18$, $p = 0.697$) between the two groups.

When considering the relationship between saccades and caffeine in this study, there were not enough data to determine significance of presence or type of saccades. A larger sample size might allow for the potential for more participants with saccades to be tested as saccades could be found in approximately half (49%) of ears without vestibular pathology (Yang et al., 2016). Having a larger sample of those with normal vestibular function, and thus a larger number of those with saccades, would allow the significance

of caffeine and saccades in the vHIT test to be explored. Another factor was the population tested consisted of individuals without vestibular dysfunction. If individuals with vestibular function had been included in the study, a higher number of those with the presence of saccades would be expected. Due to this study's sample size and the even smaller set of data with the presence of saccades, it would be difficult to determine statistical significance at this time.

Caffeine's Effect on Balance

While many of the studies discussed involved the vestibular system, it is only one of the three systems that contributes to balance; the other are the visual system and proprioceptive system. There is some differing evidence on caffeine's effect on the overall balance system. Enriquez, Sklaar, Viirre, and Chase (2009) found no effect of caffeine on postural stability in young, healthy adults. They tested 23 participants ages 18-23 before and after caffeine consumption, as well as with and without their eyes open, by having them stand on a platform that measured their center of balance. No significant difference was seen between the two test conditions. Kim, Choi, Yoon, and Kwon (2014) also observed the effects of caffeine on postural stability in participants by comparing a healthy group of 15 adults to a group of 30 patients who had experienced a stroke. They found that while caffeine had no effect on the healthy group in both a vision-allowed and vision-denied condition, there was a statistically significant improvement in postural stability in participants who had experienced stroke when they were vision-denied (Kim et al., 2014).

Caffeine has been shown to have an effect on the visual system as well. Coren (2002) administered varying levels of caffeine (placebo, 100 mg, or 200 mg) for 20

participants who were then asked to look at various visual patterns to test the level of visual instability. With increasing levels of caffeine, participants reported an increased number of visual disturbances. These results suggested that caffeine, and the increased cortical arousal associated with it, might interact with the visual cortex and increase perceptual instability, especially when looking at patterns (Coren, 2002).

Differences in Methods

When comparing the current study to the literature reviewed, a slight difference in methods was noted. As previously stated, this study compared a group that was given decaffeinated coffee and a group that was given caffeinated coffee, both of which abstained from caffeine consumption prior to the first test. The current study was the only one noted that used decaffeinated coffee for a control group. Other studies, such as Felipe et al., 2005, also tested the same participants twice—first with caffeine cessation for 24 hours and then five days later without any caffeine cessation. McNerney et al. (2014a), McNerney et al. (2014b), and McNerney et al. (2018) tested participants twice—once after drinking a 16 oz cup (estimated 300 mg caffeine) of Breakfast Blend coffee from Starbucks after abstaining from caffeine that morning and again on a different day after abstaining from caffeine for 24 hours. Using decaffeinated coffee as a control, estimated to have approximately 20 mg of caffeine, could potentially have been a confounding factor in this study. Other studies used placebos without any caffeine content or did not require that their participants be blind or use a placebo.

Another difference between methods was the calculation of caffeine dose. This study—as well as McNerney et al. (2014a), McNerney et al. (2014b), and McNerney et al. (2018)—used a set amount of caffeine. In this study, each person was estimated to

have 270 mg caffeine. In other studies, the amount of caffeine consumed was determined based on body weight. For example, Smith et al. (2003) used 1.5 mg/kg body weight, Dixit et al. (2006) used 3 mg/kg body weight, and Connell et al. (2017) used 5 mg/kg body weight.

Felipe et al. (2005) tested participants who reported drinking an average of 200-300 mg of caffeine per day and tested them with and without cessation of their typical caffeine intake. In the current study, participants were screened regarding whether they were "regular caffeine consumers" but specific average doses were not obtained. This information would have been helpful to have, in case an effect was seen based on a participant's typical caffeine intake, and should be collected should this study be repeated.

Left Versus Right Ears

The gain values of the left and the right ears were compared to determine if the test administration was affected by the side tested. When testing participants, it was noted the gain measurements for the left ear tended to be slightly lower than those of the right ear. A two-tailed *t*-test performed in Microsoft Excel showed a significant difference between the left gain measurements and right gain measurements ($t(65) = -3.79$, $p = .000328$).

A possible explanation for these findings could be a bias in head rotation in one direction compared to the other on the part of the tester. However, another possible explanation could be the fact that the right eye was the one tracked by the goggles. This explanation was discussed by McGarvie, MacDougall et al. (2015) who also found the head impulses to the right to be slightly, though significantly, higher than those to the

left. McGarvie, MacDougall et al. defined the gain as the ratio of the eye movement response to the head movement stimulus. Because the right eye was being tracked, it had a larger rotation to make when the head was turned to the right than when it was turned to the left in order to remain fixated on the dot (McGarvie, MacDougall et al., 2015), thus resulting in a higher gain value. No further explanations could be found in the literature.

These results aligned with those found by Yang et al. (2016) who also found a significant difference between right and left gain values ($p < .05$) when testing 50 normal adult participants as well as results found by Bachmann et al. (2018) when testing 41 pediatric participants ($p < .001$). A meta-analysis could be completed to compare findings by these studies.

Study Limitations

Several limitations to this study should be addressed, many of which had to do with the sample. One of these limitations was the size of the sample used ($N = 18$). A larger sample size would be beneficial to be able to conduct a large-scale analysis of the effects of caffeine on the vHIT. Conducting this study on a larger scale would be helpful in verifying results obtained by this study. A larger sample size would also allow for a more representative sample, which brought up another limitation—the demographics of the study. The sample used for this study was predominantly female (73.68%) and young with most participants in their 20s (78.95%). Groups 1 and 2 were also not balanced regarding age and gender demographics, although no obvious trends related to these factors were noted. Only four participants were above 30 years of age, all of whom were in group 2 (decaffeinated) and there were only five male participants, four of whom were

in group 1 (caffeine). Because of the imbalance, it was difficult to observe trends if they did exist.

Another limitation was the consistency of the caffeine dose that was administered to participants in group 1. The type of caffeinated coffee used, Starbucks Blonde Roast, was obtained from a local Starbucks store. While Starbucks reports an estimation of caffeine content, it was not possible to ensure each participant was given the same amount of caffeine due to the possibility of variations in caffeine content between cups.

Although recruitment criteria required participants to be somewhat regular consumers of caffeine, participants were not further screened regarding their caffeine consumption. This further information would have allowed typical caffeine consumption to be explored as a factor in how caffeine affected vHIT results. If someone was a frequent caffeine consumer, their results might not have been affected as much as if someone consumed caffeine only one to two times per week, such as results observed by McNerney et al. (2018).

The last limitation was the inexperience of the researcher. As the researcher was a graduate student with limited time and experience with performing vHIT on patients, there was the potential for bias in head movement in one direction or the other. This limitation was possibly shown in the fact that a significant difference in gain values was seen between the left and right ears. However, because other researchers have observed this trend, this might not have been the case. A way to determine if the inexperience of the test administrator had an effect would be to repeat the testing using multiple testers.

Future Research

The results of this study provided a starting point from which future research could be explored. While this study included participants without vestibular pathology, future studies should determine if there would be an effect of caffeine on those with known vestibular pathologies or disorders.

With the use of a larger sample size, further parameters could be analyzed. For example, the effect of caffeine on the presence of saccades could be studied. Additionally, a larger sample size would allow the effect of the dose of caffeine to potentially be explored. To determine if the amount of caffeine had an effect on results, a study could be designed that compared test results after the administration of differing amounts of caffeine.

Future research could also be completed that included the measurement of gain in the RALP and LARP conditions in order to have a complete set of vHIT results. Getting a comprehensive test would also allow other left versus right asymmetries in VOR to be further explored.

Conclusion

The purpose of this study was to determine if there would be a difference in VOR gain values recorded by the vHIT when comparing a group of adults who ingested caffeine to another group who ingested a decaffeinated beverage. The vHIT response was measured before and after caffeine consumption for each group. While a statistically significant difference was seen in the change in VOR gain from pre- to post-coffee consumption between group 1 and group 2, this significance was only seen when using absolute values of the difference values between the two test conditions. Because there

was no statistical significance in these difference values between group when absolute values were not used, further conclusions regarding the direction of the change in VOR gain values could not be made. Another trend noted was more saccades were seen in group 2, which had consumed decaffeinated coffee, but this finding was also not statistically significant.

However, the differences in VOR gain values and the number of saccades observed for each group were not clinically significant, i.e., all of the participants in both groups would have been classified as having normal test results in a clinical setting regardless of coffee consumption. The results of this study suggested that abstaining from caffeine might not be necessary when performing the vHIT clinically.

Due to reasons discussed in this section, further studies should be completed on a larger scale or with the use of multiple testers to verify these findings. While these results were helpful in better understanding testing for normal, healthy participants, these participants were often not the typical population tested at clinics or hospitals. Studies performed by researchers exploring caffeine and the vestibular system should be repeated on those with vestibular disorders to determine how these findings translated to this population, which was arguably more clinically relevant than testing those without vestibular pathology.

The results of this study provided clinicians more insight into the vHIT as well as how to properly prepare their patients for this vestibular evaluation. With the potential for future research, this knowledge base will continue to grow and provide a better understanding to those performing these tests.

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APPENDIX A

INSTITUTIONAL REVIEW BOARD APPROVAL

UNIVERSITY OF
NORTHERN COLORADO

Institutional Review Board

DATE:	December 2, 2019
TO:	Elizabeth Zakrzewski
FROM:	University of Northern Colorado (UNCO) IRB
PROJECT TITLE:	[1481015-2] The Effects of Caffeine on Video Head Impulse Test Results
SUBMISSION TYPE:	Amendment/Modification
ACTION:	APPROVED
APPROVAL DATE:	December 2, 2019
EXPIRATION DATE:	*See note in bold below*
REVIEW TYPE:	Expedited Review

Thank you for your submission of Amendment/Modification materials for this project. The University of Northern Colorado (UNCO) IRB has APPROVED your submission. All research must be conducted in accordance with this approved submission.

This submission has received Expedited Review based on applicable federal regulations.

Please remember that informed consent is a process beginning with a description of the project and insurance of participant understanding. Informed consent must continue throughout the project via a dialogue between the researcher and research participant. Federal regulations require that each participant receives a copy of the consent document.

Please note that any revision to previously approved materials must be approved by this committee prior to initiation. Please use the appropriate revision forms for this procedure.

All UNANTICIPATED PROBLEMS involving risks to subjects or others and SERIOUS and UNEXPECTED adverse events must be reported promptly to this office.

All NON-COMPLIANCE issues or COMPLAINTS regarding this project must be reported promptly to this office.

Under the recently revised Common Rule, this project will not require annual continuing review by the committee. Your project has been assigned a "Next Report Due" date of December 2, 2022. Just prior to that date, the IRB will check in with you to get a current status of your project. This will help us determine if your project needs to be extended or if your study is ready to be closed. If you have completed your project prior to that date, please contact the Office of Research & Sponsored Programs to complete a closing report.

Please note that all research records must be retained for a minimum of three years after the completion of the project.

If you have any questions, please contact Nicole Morse at 970-351-1910 or nicole.morse@unco.edu. Please include your project title and reference number in all correspondence with this committee.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within University of Northern Colorado (UNCO) IRB's records.

APPENDIX B

CONSENT FORM FOR HUMAN PARTICIPANTS IN RESEARCH

CONSENT FORM FOR HUMAN PARTICIPANTS IN RESEARCH
UNIVERSITY OF NORTHERN COLORADO

Project Title: The Effects of Caffeine on Video Head Impulse Test Results
Researcher: Elizabeth Zakrzewski, Student, Department of Audiology and Speech Language Sciences
Phone: 802-375-4297, E-mail: zakr4034@bears.unco.edu
Research advisors: Tina Stoody, Ph.D., and Kathryn Bright, Ph.D.

Purpose and Description: The purpose of this research is to determine the effect of caffeine on video head impulse test (vHIT) measures. The vHIT is a fairly new balance evaluation tool. The researcher will perform vHIT testing on you at two time points, once before coffee consumption and once after.

For the first testing session, you will sit in a chair facing a wall, approximately a meter away. You will wear a set of special goggles that have a camera to track your eye movements, which will be strapped tightly to your head to ensure they do not slip during testing. The goggles' camera will be calibrated, which will involve following a light on the wall with your eyes. Once calibration is completed, testing will begin. During testing, your head will be turned to the left and right by the researcher in short, swift movements, while the camera measures your eye movements. To make the head movements, the researcher will place her hands on the top of your head. Once enough data points are collected (20 measurements to each side), the first testing session will be complete, and the goggles will be removed. It is estimated that this portion of testing will take 20-25 minutes.

Between sessions, you will be taken to another room and given a cup of coffee, which will be either caffeinated or decaffeinated. Neither you nor the researcher will know which type of coffee you are given during the testing period. You will be allowed to put cream and/or sugar in your coffee. A 45 minute timer will be started once you are approximately halfway done with the beverage. Once the time has passed, the second vHIT testing session will begin. The second testing session will be completed in the same manner as the first.

When testing is completed, we will share your data with you at your request. We will take precautions in order to protect your anonymity including assigning a subject number to you. Only the lead investigator and her assistants will know the name connected with a subject number and when we report data, your name will not be used.

Potential risks in this project are minimal, and are no more than those encountered in everyday life. The consumption of coffee required for this study would not exceed 400 mg of caffeine, i.e. the typical daily recommended amount for adults, and therefore is not considered a risk. Testing procedures may cause minor neck discomforts due to head movements made.

No direct compensation is being provided for participation in this study. Indirect benefits from this study will include the better understanding of the test by audiologists.

Participation is voluntary. You may decide not to participate in this study and if you begin participation you may still decide to stop and withdraw at any time. Your decision will be respected and will not result in loss of benefits to which you are otherwise entitled. Having read

the above and having had an opportunity to ask any questions, please sign below if you would like to participate in this research. A copy of this form will be given to you to retain for future reference. If you have any concerns about your selection or treatment as a research participant, please contact Nicole Morse, Office of Research and Sponsored Programs, Kepner Hall, University of Northern Colorado Greeley, CO 80639; 970-351-1910.

_____		_____	
Subject's Signature	Date	Researcher's Signature	Date

APPENDIX C

GAIN VALUES BY SUBJECT

vHIT Data

Subj	Age	Gender	Coffee	Ear	Gain, pre-coffee	Gain, post-coffee	Difference Values	Overt Saccades	Covert Saccades
1	24	F	Caffeine	Left	1.01	0.92	0.09	0	0
				Right	1.11	1.02	0.09	0	0
2	24	F	Decaf	Left	0.93	0.99	-0.06	0	0
				Right	1.06	1.09	-0.03	0	0
3	25	M	Caffeine	Left	0.90	1.00	-0.10	0	0
				Right	1.06	1.11	-0.05	0	0
4	24	F	Decaf	Left	1.00	0.95	0.05	0	0
				Right	1.08	1.01	0.07	0	0
5	27	M	Decaf	Left	1.00	0.96	0.04	0	0
				Right	0.99	0.99	0.00	2	0
6	26	F	Decaf	Left	0.95	0.94	0.01	0	2
				Right	1.00	1.01	-0.01	0	0
7	22	M	Caffeine	Left	0.87	0.91	-0.04	2	0
				Right	0.97	0.97	0.00	0	0
8	57	F	Decaf	Left	0.96	0.95	0.01	0	3
				Right	1.08	1.02	0.06	0	0
9*	23	F	Caffeine	Left	0.90	0.77	0.13	2	0
				Right	1.01	0.99	0.02	6	0
10	24	F	Decaf	Left	0.97	0.96	0.01	0	0
				Right	0.98	0.98	0.00	0	0
11	23	F	Caffeine	Left	0.90	0.92	-0.02	10	2
				Right	0.98	0.94	0.04	6	0
12	23	F	Caffeine	Left	0.94	1.03	-0.09	0	0
				Right	0.82	0.92	-0.10	0	0
13	22	M	Caffeine	Left	1.00	1.01	-0.01	0	0
				Right	0.98	1.03	-0.05	0	0
14	22	F	Caffeine	Left	0.92	0.89	0.03	0	0
				Right	0.94	0.93	0.01	0	0
15	35	F	Decaf	Left	1.00	0.96	0.04	0	0
				Right	1.08	1.02	0.06	0	0
16	22	M	Caffeine	Left	0.97	0.90	0.07	0	0
				Right	1.03	0.98	0.05	0	0
17	23	F	Caffeine	Left	0.97	0.83	0.14	2	2
				Right	1.00	0.89	0.11	2	0
18	65	F	Decaf	Left	0.99	1.01	-0.02	27	0
				Right	1.00	1.02	-0.02	12	0
19	58	F	Decaf	Left	0.87	0.92	-0.05	4	0
				Right	0.95	0.94	0.01	7	0

* = Excluded from data analysis